

3. RADIONUCLIDE CONTAMINANTS IN THE ENVIRONMENT

Waste-zone, vadose-zone, and aquifer samples are routinely collected around the RWMC and analyzed for a variety of radionuclides. Results from monitoring of radionuclides for FY 2002 are presented in this section. Data collected since FY 1997 also are summarized for perspective and to identify trends or lack thereof.

Radionuclide concentrations greater than 3σ and greater than the sample-specific minimum detectable activity (MDA) are referred to throughout this section as positive detections. Concentrations that are greater than 2σ and greater than or equal to 3σ are referred to as statistically positive detections. Section 4.5.2 of the ABRA provides more discussion on the definition of positive detections, statistical detections, nondetections, and radiological uncertainty.

When the laboratory analysis results in a statistically positive detection of one or more actinides (i.e., Am-241, Np-237, Pu-238, Pu-239/240) in water samples, the laboratory pulls another aliquot from the sample container and conducts another analysis of the sample to confirm the detection. When the second analysis fails to confirm the presence of the actinide, the result is referred to throughout this section as an unconfirmed detection. Recently, the protocol for lysimeter samples has been changed so that confirmation analyses are not conducted for actinide detections. The revised actinide protocol for lysimeters favors acquisition of data for various analytes over confirmation of sporadic actinide detections, and is being implemented in FY 2003.

3.1 Americium-241

Approximately $1.83\text{E}+05$ Ci of Am-241 were disposed of in the SDA, and approximately $3.25\text{E}+04$ Ci of Am-241 are expected to be generated over time through Pu-241 ingrowth. The primary source of Am-241 and Np-237 in the SDA is the Rocky Flats Plant (RFP)^a Series 741 sludge (i.e., first stage wastewater sludge). An area in the central part of Pit 10 was identified as the Americium/Neptunium Focus Area for the Integrated Probing Project.

3.1.1 Waste Zone

Three waste zone soil moisture samples were collected and analyzed for Am-241 in FY 2002, with no positive detections. The samples were collected from Lysimeter 741-08-L1, which is located in the Americium/Neptunium Focus Area of Pit 10.

3.1.2 Vadose Zone

3.1.2.1 Lysimeter Samples at Depths of 0 to 35 ft. Nine shallow-lysimeter samples were collected and analyzed for Am-241 in FY 2002, with no positive detections at depths of 0 to 35 ft. The lysimeter samples were collected in April and July 2002. Results for Am-241 in the shallow vadose-zone samples since FY 1997 are summarized in Figure 3-1. Sporadic detections occur, but no apparent trends for Am-241, in the shallow lysimeters.

3.1.2.2 Lysimeter Samples at Depths of 35 to 140 ft. Twelve lysimeter samples were collected from the intermediate depth range (35 to 140 ft) and analyzed for Am-241 in FY 2002,

a. The Rocky Flats Plant is located 26 km (16 mi) northwest of Denver. In the mid-1990s, it was renamed the Rocky Flats Environmental Technology Site. In the late 1990s, it was again renamed, to its present name, the Rocky Flats Plant Closure Project.

FY	Qtr	98-1L35	98-4L38	98-5L39	D15-DL07	PA01-L15	PA02-L16	PA03-L33	W05-L25	W06-L27	W08-L13	W08-L14	W09-L23	W23-L07	W23-L08	W23-L09	W25-L28
1997	1																
	2																
	3																
	4																
1998	1																
	2							4.2									
	3					9											
	4																
1999	1			0.8												0.8	
	2																
	3																
	4																
2000	1																
	2			0.30													
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
		Analysis was performed, but Am-241 was not detected.															
		Am-241 detected (pCi/L).															
Key		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: RBC = 4.76 pCi/L															
		RBC = 1E-05 risk-based concentration															

Figure 3-1. Occurrences of Am-241 detections in the shallow lysimeters since FY 1997.

with no positive detections. The lysimeter samples were collected in April and July 2002. Results for the intermediate vadose zone samples since FY 1997 are summarized in Figure 3-2. There are sporadic detections, but no apparent trends for Am-241 in the intermediate depth lysimeters.

3.1.2.3 Lysimeter Samples at Depths Greater than 140 ft. One perched water sample and seven lysimeter samples were collected in the 140-ft depth range and analyzed for Am-241 in FY 2002, with no positive detections. The perched water sample was collected from USGS-92 in January 2002 and the lysimeter samples were collected in April 2002 (Lysimeters I2D-DL10, I3D-DL12, I4D-DL14, and O8D-DL29) and July 2002 (Lysimeters I3D-DL12, O6D-DL26, and O7D-DL27). No detections of Am-241 have occurred in any perched water or vadose zone samples at this depth interval in the 5-year reporting period addressed in this report.

FY	Qtr	D06-DL01	D06-DL02	D15-DL06	I1S-DL09	I2S-DL11	I3S-DL13	I4S-DL15	I5S-DL16	O2S-DL20	O3S-DL22	O4S-DL24	O5S-DL25	O7S-DL28	TW1-DL04
1997	1														
	2														
	3														
	4														
1998	1														
	2														
	3			2.4											
	4														
1999	1	0.8													
	2														
	3														
	4														
2000	1														
	2														1.9
	3														
	4														
2001	1														
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
Key		Analysis performed, but Am-241 was not detected.													
		Am-241 was detected (pCi/L)													
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.													
		Note: RBC = 4.76 pCi/L. RBC = 1E-05 risk-based concentration													

Figure 3-2. Occurrences of Am-241 detections in intermediate-depth (35 to 140 ft) lysimeters since FY 1997.

3.1.3 Aquifer

Sixty-three aquifer samples were collected from 15 RWMC monitoring wells and analyzed for Am-241 in FY 2002, with no positive detections. Samples were collected in November and December 2001, and February, May, and September 2002. The results are summarized in Figure 3-3. Ten of the 63 aquifer samples required reanalysis because the results were statistically positive, but the reanalyses did not yield any positive detections. Results for the aquifer samples since FY 1997 show sporadic detections but no evident trends.

FY	Qtr	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS- 127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
Key	1	Analysis was performed, but Am-241 not detected.															
	2	Am-241 detected (pCi/L).															
	3	If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
	4	Note: RBC = 4.76 pCi/L. MCL=15 pCi/L total alpha. MCL = maximum contaminant level RBC = 1E-05 risk-based concentration															

Figure 3-3. Occurrences of Am-241 detections in aquifer samples around the Radioactive Waste Management Complex since FY 1997.

3.1.4 Summary of Americium-241

Americium-241 was not detected in any of the soil moisture or aquifer samples collected in FY 2002. Historical detections in the vadose zone are depicted with the locations of waste disposals known to contain Am-241 (see Figure 3-4). All but one of the mapped detections are one-time events that have not been substantiated with subsequent detections in more than 2 years. Two detections were made in Lysimeter 98-5L39, located on the west end of the SDA near some mapped disposals, but no positive detections have been found in the three sampled quarters since the second quarter of FY 2000. Aquifer detections of Am-241 also are sporadic. Sporadic detections of Am-241 in the vadose zone and the aquifer since 1997 do not point to any evident spatial or temporal trends.

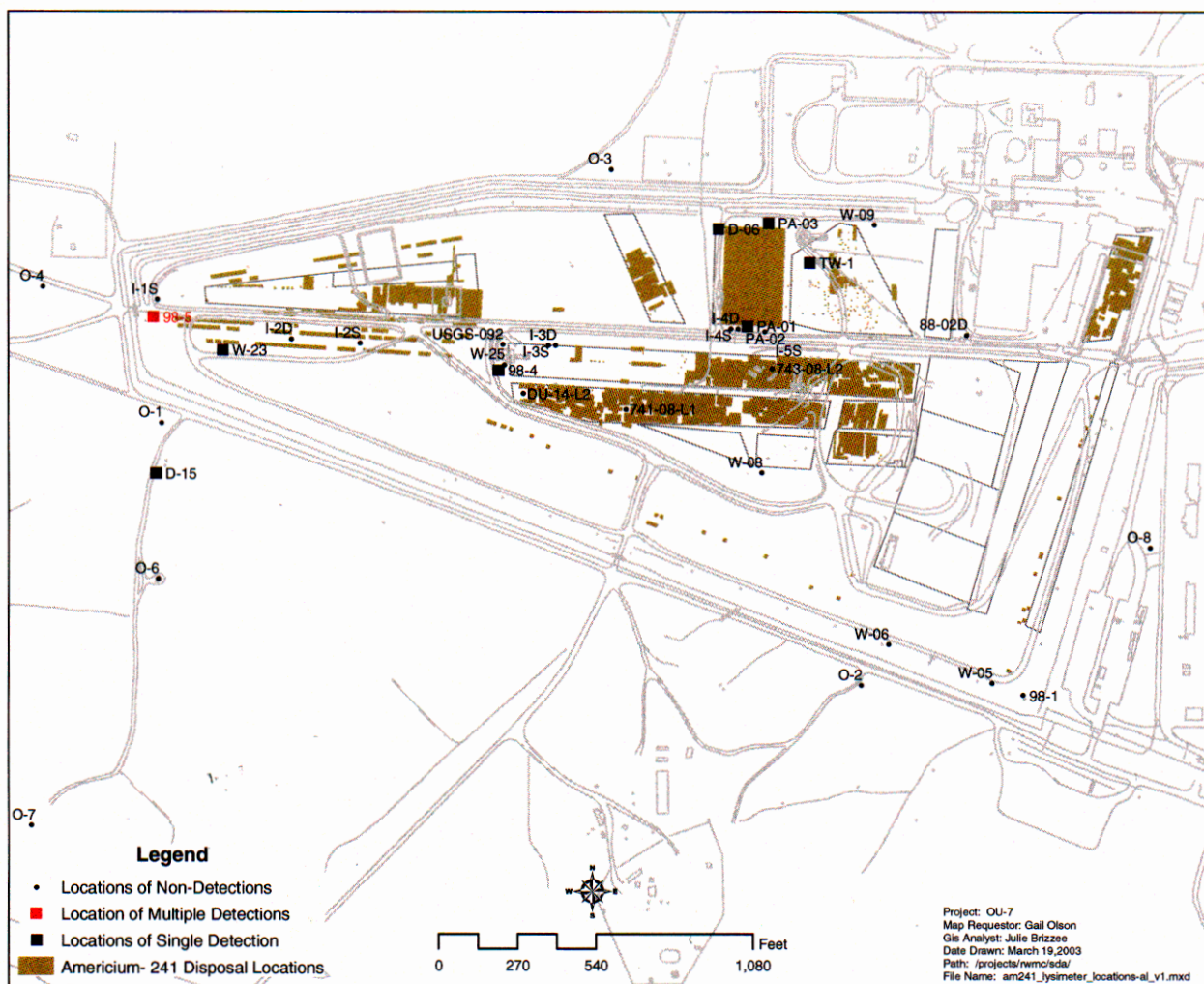


Figure 3-4. Americium-241 disposal locations and vadose zone detection locations at the Subsurface Disposal Area.

3.2 Carbon-14

Carbon-14 is generated by nuclear operations as an activation product. Most of the C-14 inventory in the SDA is from disposal of activated steel. Some of the disposal inventory is in the form of reactor core components, including beryllium reflector blocks and end pieces from reactor cores. The remaining activity is mostly in ion exchange resins. Typical C-14-bearing waste was disposed of in the SVRs or trenches in the earlier years of operation.

Soil Vault Rows 12 and 20 in the southeast corner of the SDA are known to contain large amounts of C-14 because of disposals of activated metal (SVR 12) and beryllium blocks (SVR 20). Soil Vault Row 12 contains numerous disposals of what is believed to be activated stainless steel. Information gathered through conversations with past and present INEEL staff (Salomon 2001) indicates these disposals are probably highly irradiated stainless steel end pieces removed from Experimental Breeder Reactor II spent fuel elements. Spent fuel elements from Experimental Breeder Reactor II were sent to the Idaho Nuclear Technology and Engineering Center (INTEC) for processing after use. The stainless steel end pieces were physically separated from the fuel in underwater basins at Chemical Processing Plant (now INTEC) facility CPP-603 before uncontained disposal (in baskets, not sealed) at RWMC. Ten shipments were sent from CPP-603 and placed in SVR 12. The rate of release of C-14 from activated steel, presumably by corrosion, is being studied at SVR 12. Type B probes with vapor ports were installed in 2001, and initial sampling was conducted in 2002. Soil Vault Row 20 contains disposed beryllium blocks from ATR, which contained approximately 20 Ci of C-14.^b

3.2.1 Waste Zone

Carbon-14 samples are collected quarterly from the functioning Type B vapor probes at SVRs 12 and 20. Sampling sites near SVRs 12 and 20 are shown in Figure 3-5. The C-14 samples are analyzed for C-14 specific activity (i.e., C-14 activity per unit mass of total carbon). This requires analysis for total carbon and total C-14 activity in the gas sample. Carbon-14 results for the functioning probes at SVRs 12 and 20 are contained in Table 3-1. The results for C-14 analysis of SVR 12 samples indicate that the C-14 specific activity is approximately two orders of magnitude above background concentrations of C-14 of about 6.5 pCi/g C. The concentration of H-3 in soil gas near SVR 12 also was measured and determined to be less than 600 pCi/L, and probably considerably less than 100 pCi/L (i.e., near background levels). The absence of H-3 in the soil gas provides confidence that the C-14 originates from activated carbon steel, rather than activated beryllium.

Specific activity of C-14 in CO₂ has been measured in grab samples of soil gas collected from the gas sampling port (GSP) -1 ports. Results for soil gas samples are summarized in Table 3-2. These results are for samples collected using caustic solutions in bubblers before FY 2000, and in Tedlar bags after FY 2000. The SVR 20-IPV-5-VP3 soil-gas sampling port is located approximately 5 m (16 ft) from the beryllium waste, and the GSP-1 gas sampling ports are located approximately 0.8 to 1 m (2.6 to 3 ft) from the waste. The specific activity of C-14 in CO₂ is approximately a factor of 3 less at the more distant location, based on the samples from both ports on November 15, 2001, and August 23, 2002.

No waste zone soil moisture samples were collected and analyzed for C-14 in FY 2002 because of arid conditions, limited sample volumes, and analytical priorities.

b. B. G. Schnitzler Letter to M. M. Garland, August 21, 1995, "Radionuclide Inventories of Advanced Test Reactor Outer Shim Control Cylinder and Reflector Block Components," BGS-12-95, INEEL.

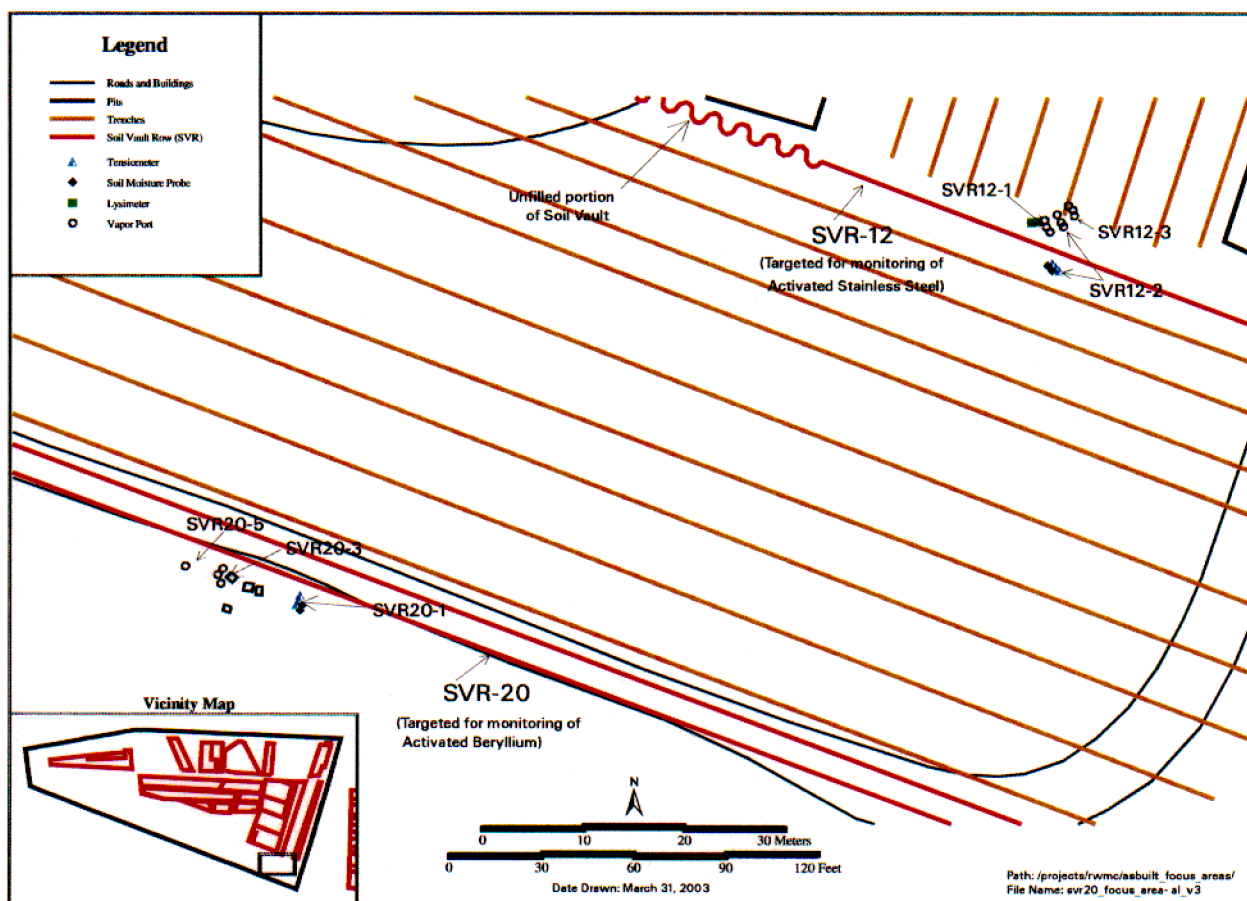


Figure 3-5. Vapor probes, tensiometers, lysimeters, and soil moisture probes installed in the waste zone near or in Soil Vault Rows 12 and 20.

Table 3-1. Specific activity of C-14 (pCi [C-14]/g [C]) from vapor probes at Soil Vault Row 12.

	SVR 12-1			SVR 12-2		SVR 12-3		
	VP1	VP2	VP3	VP1	VP2	VP1	VP2	VP3
Depth (m)	11.7	7.6	2.7	11.9	7.7	11.8	7.6	2.5
Date								
12/03/01	220	190	460	120	240	190	170	500
2/20/02	2,050	450	14,900	1,400	—	2,000	1,500	16,300
5/23/02	990	990	2,820	1,370	310	1,220	1,620	370
8/13/02	871	341	26,500	494	494	436	3,090	1,240
11/13/02	711	556	327	1,510	594	1,110	677	1,430

Table 3-2. Summary of C-14 specific activity (pCi [C-14]/g [C]) in CO₂ from soil gas samples collected at Soil Vault Row 20.

	GSP-1	GSP-1	GSP-1	SVR 20-IPV-5-VP3
Depth (m)	2.7	4.5	6.2	5.4
Date				
6/5/1996	1.70E+04	—	2.30E+04	—
7/2/1996	—	3.40E+04	2.50E+04	—
12/12/1996	1.30E+05	4.20E+04	3.30E+04	—
11/12/1997	4.40E+04	2.00E+04	1.20E+04	—
11/15/2001	3.64E+05	1.58E+05	2.45E+05	8.28E+04
2/20/2002	—	—	—	2.85E+04
5/2/2002	1.71E+05	1.45E+05	1.33E+05	—
5/23/2002	—	—	—	3.10E+04
8/23/2002	1.34E+05	1.33E+05	1.37E+05	3.67E+04
GSP = gas sampling port SVR = soil vault row				

3.2.2 Vadose Zone

3.2.2.1 Lysimeter Samples at Depths of 0 to 35 ft. Two soil moisture samples were obtained in FY 2002 from the depth range of 0 to 35 ft and analyzed for C-14, with no positive detections. The samples were collected in July 2002. Results for C-14 in shallow vadose zone samples since FY 1997 are summarized in Figure 3-6.

3.2.2.2 Lysimeter Samples at Depths of 35 to 140 ft. One soil moisture sample was obtained in FY 2002 from the depth range of 35 to 140 ft and analyzed for C-14, with no positive detections. The sample was collected in April 2002 from Lysimeter IIS-DL09. No detections of C-14 have been made in intermediate-depth lysimeter samples since monitoring began in 1997.

3.2.2.3 Lysimeter and Perched-water samples at Depths Greater than 140 ft. One perched water sample was obtained in FY 2002 at depths of more than 140 ft and analyzed for C-14, with an unconfirmed positive detection as shown in Table 3-3. Two unconfirmed detections of C-14 in Well USGS-92 occurred in 1997 (12 ± 3 pCi/L in April and 13 ± 2 pCi/L in August) and a confirmed detection in February 1998 (20 ± 4 and 14 ± 4 pCi/L). In addition, an unconfirmed detection of C-14 in Well 8802D occurred in February 1998 (20 ± 4 pCi/L) (Holdren et al. 2002).

FY	Qu	98-1L35	98-4L38	98-5L39	D15-DL07	PA01-L15	PA02-L16	PA03-L33	W05-L25	W06-L27	W08-L13	W08-L14	W09-L23	W23-L07	W23-L08	W23-L09	W25-L28
1997	1																
	2						16			11							
	3						19										
	4																
1998	1																
	2						21.8										
	3																
	4																
1999	1																
	2		24				26										
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
Key		Analysis was performed, but C-14 was not detected.															
		C-14 detected (pCi/L.)															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: RBC = 307 pCi/L															
		RBC = 1E-05 risk-based concentration															

Figure 3-6. Occurrences of carbon-14 detections in shallow lysimeters since FY 1997.

Table 3-3. Carbon-14 detections in FY 2002 Subsurface Disposal Area vadose zone samples.

Lysimeter or Perched-water well	Depth (ft)	Sample Date	Sample Volume (mL)	Sample Concentration $\pm 1\sigma$ (pCi/L)	MDA ^a (pCi/L)	RBC ^b (pCi/L)	Sample Identifier	Limitations and Validation Report Identifier
USGS-92	214	1/15/02	250	134 \pm 38 ^c	49	307	SDAS2401C6	BAM-23-02

a. The MDA is commonly referred to as the detection limit, and is a unique to each individual sample analysis result.

b. The RBC does not apply to soil moisture samples, and is provided only as a basis for comparison.

c. The sample was filtered because of suspended solids. Carbon-14 was not detected in the solids.

MDA = minimum detectable activity

RBC = 1E-05 risk-based concentration

3.2.3 Aquifer

Sixty-three aquifer samples were collected in FY 2002 from 15 RWMC monitoring wells and analyzed for C-14, with five positive detections as shown in Table 3-4. Samples were collected in November and December 2001, and February, May, and September 2002. Ten of the aquifer samples collected in September 2002 required reanalysis because the laboratory inadvertently contaminated the samples with C-14 during the sample-preparation process. Carbon-14 was not detected in nine of the 10 reanalyzed samples. No further C-14 analyses were performed on these samples. Carbon-14 occurrences in aquifer samples are summarized in Figure 3-7. Carbon-14 is detected more regularly in upgradient wells.

Table 3-4. Carbon-14 detections in Radioactive Waste Management Complex aquifer monitoring wells in FY 2002.^a

Well	Sample Date	Detected Concentration $\pm 1\sigma$ (pCi/L)	Minimum Detectable Activity (pCi/L)	Sample Identifier ^b
M15S	2/25/02	4.5 ± 0.9	2.9	RISM3901U7
M17S	2/20/02	7.5 ± 0.9	2.9	RISM4101U7
AllA31	5/21/02	3.1 ± 0.9	2.9	RISM7301U7
AllA31	9/16/02	7.1 ± 0.8	3.1	RISN1301U7
M4D	9/11/02	3.5 ± 1.0	3.3	RISN0201U7

a. MCL = 2,000 pCi/L.

b. Limitations and validation report identifier associated with each sample identifier is DNT-091-02 (RISM3901U7 and RISM4101U7), DNT-164-02 (RISM7301U7), and SOS-TL08-02 (RISN1301U7 and RISN0201U7).

FY	Qtr	AI1A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4				3.0	6.7											
1999	1																
	2				4.4						4.9						
	3																
	4						10.9										
2000	1													5.27	1.8		
	2																
	3																
	4				2.1	3.2	4.0				2.8	3.3			2.2		
2001	1																
	2																
	3			2.8	2.9	3.3											4.5
	4									42.1							
2002	1																
	2							4.5		7.5							
	3	3.1															
	4	7.1											3.5				
Key		Analysis was performed, but C-14 not detected.															
		C-14 detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: RBC=307 pCi/L. MCL=2,000 pCi/L.															
		MCL = maximum contaminant level															
		RBC = 1E-05 risk-based concentration															

Figure 3-7. Occurrences of carbon-14 detections in the aquifer monitoring wells since FY 1997.

3.2.4 Summary of Carbon-14

Carbon-14 in soil gas samples collected near the beryllium block disposals in SVR 20 are approximately four orders of magnitude higher than background levels. Results for C-14 analysis in the waste zone at SVR 12 indicate that the C-14 specific activity is approximately two orders of magnitude higher than the background level of 6.5-pCi of C-14 per gram of carbon. The concentration of C-14 in soil-gas samples near activated steel (SVR 12) is much lower than the concentration observed near activated beryllium (SVR 20). This difference is as expected because of the relatively low concentration of C-14 in stainless steel and the much slower corrosion rate of stainless steel.

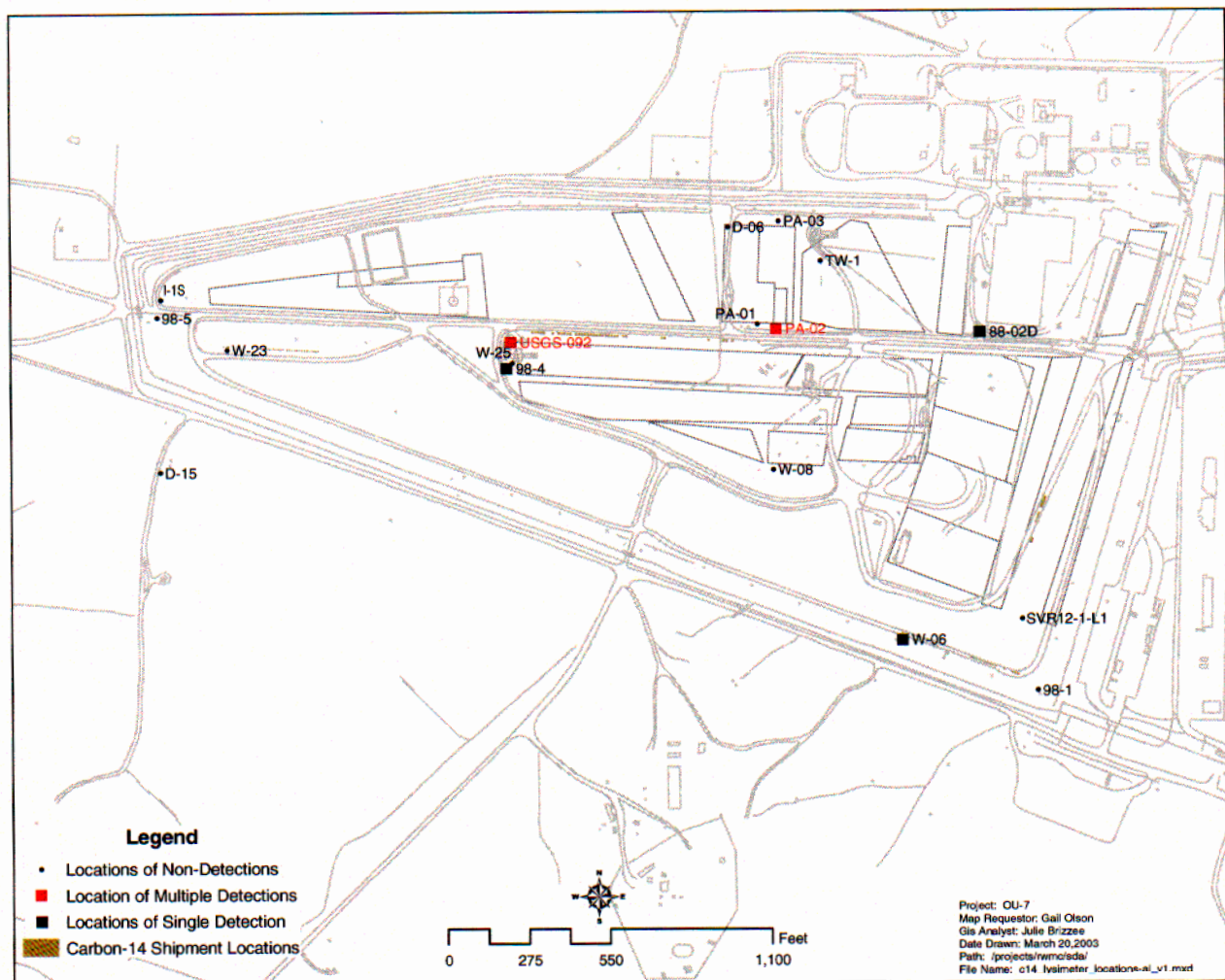


Figure 3-8. Carbon-14 disposal locations and vadose zone detection locations at the Subsurface Disposal Area.

Maximum concentrations of C-14 in vadose zone soil moisture and perched water since FY 1997 are shown in Table 3-5, and locations of detected C-14 in vadose zone samples are depicted in Figure 3-8 along with the known C-14 disposals. Carbon-14 was not detected in soil moisture samples collected from the vadose zone in FY 2002, but was detected in the perched water sample from Well USGS-92. Previous detections were found in samples from USGS-92 in 1997 and 1998 suggesting that C-14 has migrated to the 67-m (220-ft) perched water region beneath the RWMC (see Holdren et al. 2002, Section 4). The concentration associated with the January 2002 sample from USGS-92 (i.e., 134 ± 38 pCi/L) is approximately 10 times higher than previous detections.

Five samples from four RWMC aquifer-monitoring wells showed positive detections of C-14 in FY 2002. Two or more detections of C-14 occurred in wells throughout the RWMC area, but the only wells that had more than two detections (Wells M12S and M13S) are located hydrologically upgradient from the RWMC. Trends are not apparent in any of the RWMC monitoring wells, and the detectable concentrations are well below the maximum contaminant level (MCL) of 2,000 pCi/L. The lack of

Table 3-5. Summary of maximum detections of carbon-14 in vadose zone soil moisture and perched-water samples at the Radioactive Waste Management Complex from FY 1997 through 2002.^a

Sampling Range (feet below land surface)	Fiscal Year ^b	Maximum Concentration $\pm 1\sigma$ (pCi/L) ^c	Sample Location
Lysimeters 0 to 35 ft	1997	19 \pm 4	PA02-L16
	1998	21.8 \pm 1.9	PA02-L16
	1999	26 \pm 5	PA02-L16
	2000	ND	Various ^d
	2001	NA	—
	2002	NA	—
Lysimeters 35 to 140 ft	1997	NA	—
	1998	ND	Various ^d
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
Perched-water wells >140 ft	1997	13 \pm 2	USGS-92
	1998	20 \pm 4	USGS-92, and 8802D
	1999	ND	USGS-92
	2000	NA	—
	2001	NA	—
	2002	134 \pm 38	USGS-92

a. MCL = 2,000 pCi/L.

b. Fiscal year spans from October 1 to September (e.g., October 1, 1996, to September 30, 1997, is FY 1997).

c. NA = Not analyzed. ND = Not detected.

d. Various locations were sampled.

FY = fiscal year

MCL = maximum concentration level

regularly occurring detections in the lysimeters or perched-water wells in the vadose zone coupled with the possibility that an upgradient source of C-14 in the aquifer suggests that C-14 would not be a good calibration target for modeling concentrations in the aquifer. Maximum detections of C-14 in the aquifer since FY 1997 are presented in Table 3-6.

Table 3-6. Summary of maximum detections of carbon-14 in the Radioactive Waste Management Complex aquifer wells from FY 1997 through 2002.^a

Fiscal Year ^b	Maximum Concentration $\pm 1\sigma$ (pCi/L)	Well Location
1997	Not detected ^c	Various ^d
1998	6.7 \pm 0.9	M13S
1999	10.9 \pm 0.7	M14S
2000	5.3 \pm 0.5	M6S
2001	42.1 \pm 1.4	M17S
2002	7.5 \pm 0.9	M17S

a. MCL = 2,000 pCi/L.

b. Fiscal year spans from October 1 to September 30 (e.g., October 1, 1996, to September 30, 1997, is FY 1997).

c. Analyzed for but not detected.

d. Various locations were sampled.

FY = fiscal year

MCL = maximum concentration level

3.3 Chlorine-36

No analytical data for Cl-36 are available from the waste zone, vadose zone or perched water before FY 2002. In FY 2002, 16 aquifer samples were collected from 15 RWMC monitoring wells and analyzed for Cl-36, with no positive detections. Samples were collected in November and December 2001 from monitoring Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127. Aquifer samples were also collected in September 2001 from the same wells and analyzed for Cl-36, with no positive detections. A summary of aquifer results is presented in Table 3-7.

Table 3-7. Summary of aquifer detection results for chlorine-36 at the Radioactive Waste Management Complex from FY 1997 through 2002.^a

Fiscal Year ^b	Maximum Concentration $\pm 1\sigma$ (pCi/L) ^c	Well Location
1997	NA	—
1998	NA	—
1999	NA	—
2000	NA	—
2001	ND	Various ^d
2002	ND	Various ^d

a. MCL = 700 pCi/L.

b. Fiscal year spans from October 1 to September 30 (e.g., October 1, 1996, through September 30, 1997, is FY 1997).

c. NA = Not analyzed. ND = Not detected.

d. Various locations were sampled.

FY = fiscal year

MCL = maximum concentration level

Currently, insufficient data for Cl-36 are available to draw any conclusions. In FY 2002, Cl-36 was added to the analytical priority list for lysimeter, perched water, and aquifer samples. Chlorine-36 is fifth on the lysimeter analysis priority list twice per year. Once a year, analysis is performed for Cl-36 in the aquifer samples. If Cl-36 is detected in the aquifer samples, then the need to intensify the aquifer sampling frequency will be reviewed.

3.4 Tritium

Tritium is produced from nuclear reactor operations and weapons manufacturing and testing, and is produced naturally in the environment by interactions of cosmic rays and atmospheric gases. About 293,000 Ci of H-3 are estimated to be disposed of in the form of six beryllium blocks buried in SVR 20, approximately 96 m (315 ft) from the east row marker. These beryllium reflector blocks were irradiated in the ATR and then taken to the SDA for disposal in 1993. Because of various fast and slow neutron reactions, the six blocks contained approximately 293,000 Ci of H-3 (predominantly as $^3\text{H}_2$, corrected for decay to 1993), and about 20 Ci of C-14 (Schnitzler 1995). The H-3 and C-14 inventories in this and other activated beryllium disposals are a substantial fraction of the total C-14 and H-3 inventory of the RWMC. Tritium and C-14 are released from the beryllium by corrosion. The H-3 activity concentration in the beryllium was estimated to be about 3 Ci/cm³, decreasing by a factor of 2 for every 2.5 cm (1 in.) away from the fuel and beryllium interface (Maheras et al. 1994). Galvanized steel canal baskets were used to contain the blocks in each shipment..

3.4.1 Waste Zone

3.4.1.1 Ambient Air Sampling. Because a substantial fraction of H-3 released from waste migrates to the atmosphere, ambient air sampling is included as part of the characterization of the waste zone and source environment. The INEEL environmental monitoring program has conducted continuous sampling for airborne H-3 at SVR 20 since 1995 (see Figure 3-9). Note that these data are reported by calendar year in accordance with requirements of the “National Emission Standards for Hazardous Pollutants” (40 CFR 61). A fixed sampler inlet was set at approximately 1 m (3 ft) above grade, approximately 1 m outside the backfilled auger hole, and downwind with respect to the nighttime primary wind direction at the RWMC. Samples are collected continuously using desiccant columns. Columns are collected when approximately 80% of the desiccant is saturated. Atmospheric humidity conditions vary through the year, so there is no definite collection period.^c

Initial measurements by the environmental monitoring group showed that H-3 concentration in air above SVR 20 ranged over several orders of magnitude during the year, with peak concentrations occurring in late summer. To develop more detailed release information, additional sampling is conducted during summer and fall. Passive airborne H-3 samplers (Wood and Workman 1992; Wood 1996) are used to sample over 1-week periods. The passive samples are collected at three heights at a location that is approximately on the edge of the backfilled auger hole, downwind with respect to the daytime primary wind direction. Results from the environmental monitoring and passive samplers show similar temporal fluctuations, but are not directly comparable because of consistent long-term differences in dispersion of H-3 to the two sampling locations. Based on results for FY 2000 through 2002, the passive samplers are exposed to air concentrations that are typically an order of magnitude greater than the environmental monitoring sampler. Estimated annual emissions of H-3 from buried activated beryllium for Calendar Year (CY) 1995 through 2001 shown in Table 3-8. Results for CY 1995 through 1999 are based on

c. The collection periods for the environmental monitoring of airborne H-3 samples have ranged from a few weeks to 3 months, depending on humidity.

environmental monitoring sampling and results for CY 2000 and 2001 are based on the passive sampling results, which are more appropriate for use with the model used to estimate emissions.

Table 3-8. Estimated annual emission of tritium to air from buried activated beryllium at Soil Vault Row 20.

Calendar Year	1995	1996	1997	1998	1999	2000	2001
Annual emission (Ci)	100	100	3	0.5	3	30	10

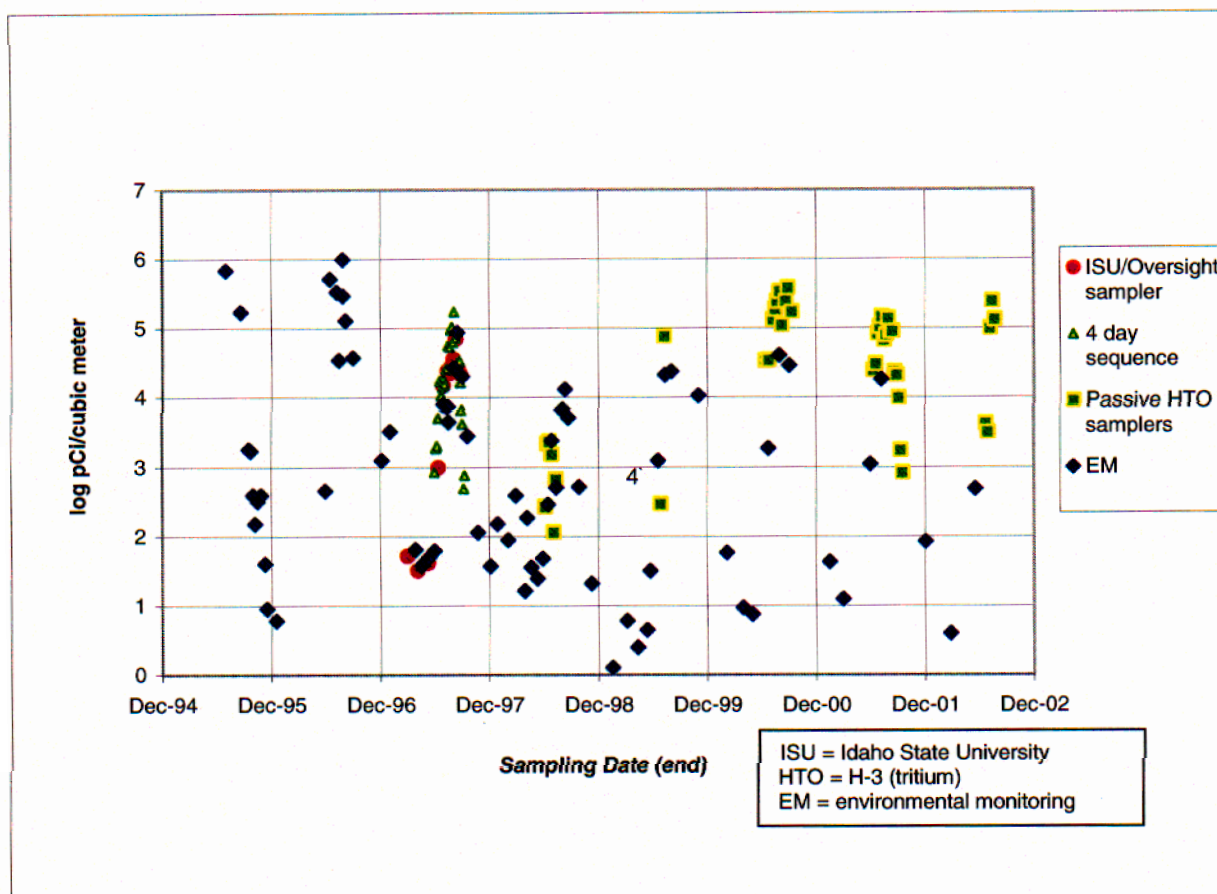


Figure 3-9. Airborne H-3 concentration above the beryllium blocks at Subsurface Disposal Area Soil Vault Row 20.

3.4.1.2 Soil Gas. Since CY 1996,⁴ soil gas samples have been collected from the GSP-1 ports, located approximately 60 to 100 cm (24 to 39 in.) from the beryllium at depths of 2.7, 4.5, and 6.2 m (8.9, 14.8 and 20.3 ft). The samples directly represent the concentrations during relatively brief sample collection periods in small (i.e., approximately 10 L), irregularly shaped volumes of soil near the ports.

d. The first samples were taken in FY 1995. No data were recovered for the 2.7-m (8.9-ft) deep sampling port because of sampling problems.

During FY 2001, the concentration of H-3 in soil moisture reached 3.5, 0.34, and 0.70 $\mu\text{Ci/mL}$ in soil 8.9, 14.8 and 20.3 ft deep, respectively (see Figures 3-10, 11, and 12). The concentration of H-3 in soil moisture appears to fluctuate with a period of one year. Fluctuations at each depth are correlated (Holdren et al. 2002), suggesting that concentrations at various depths are influenced similarly by soil and source conditions. From FY 1996 through FY 2002, H-3 concentrations in soil increased at a progressively greater rate, and current concentrations are approximately an order of magnitude higher than in FY 1995.

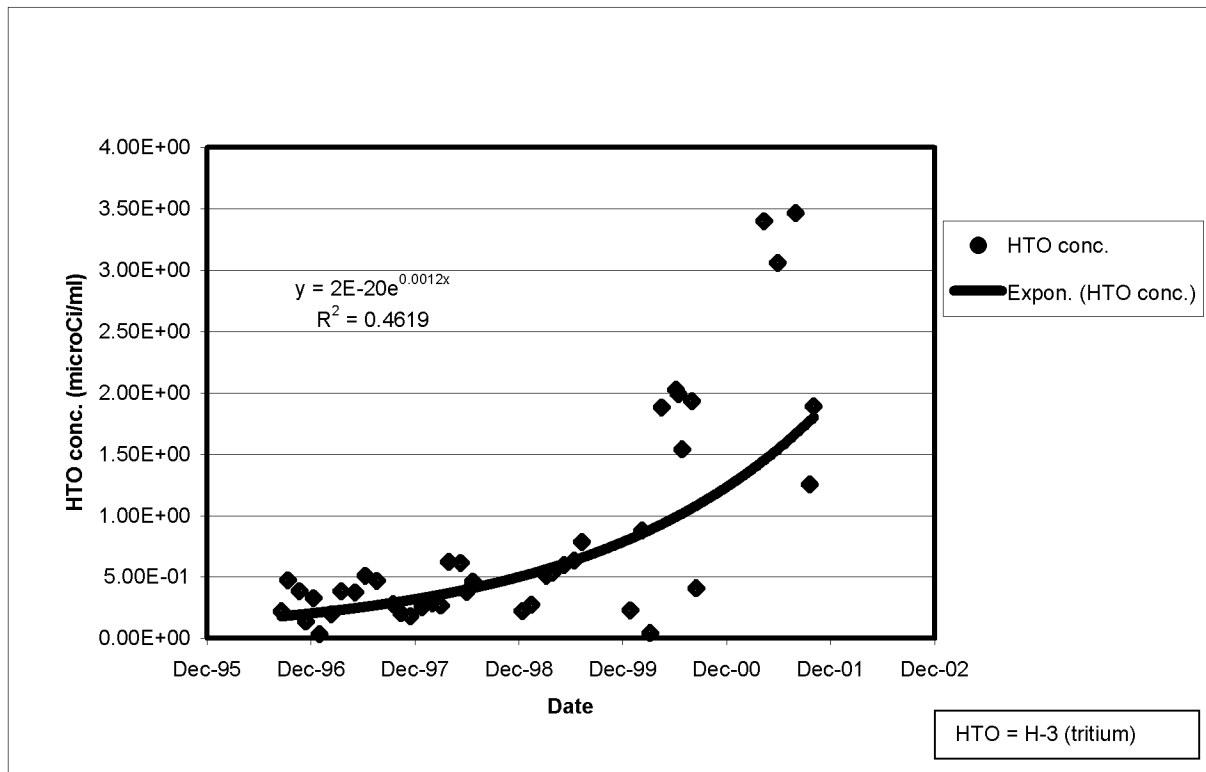


Figure 3-10. Tritium concentration in water vapor from the 8.8-ft deep GSP-1 soil gas sampling port.

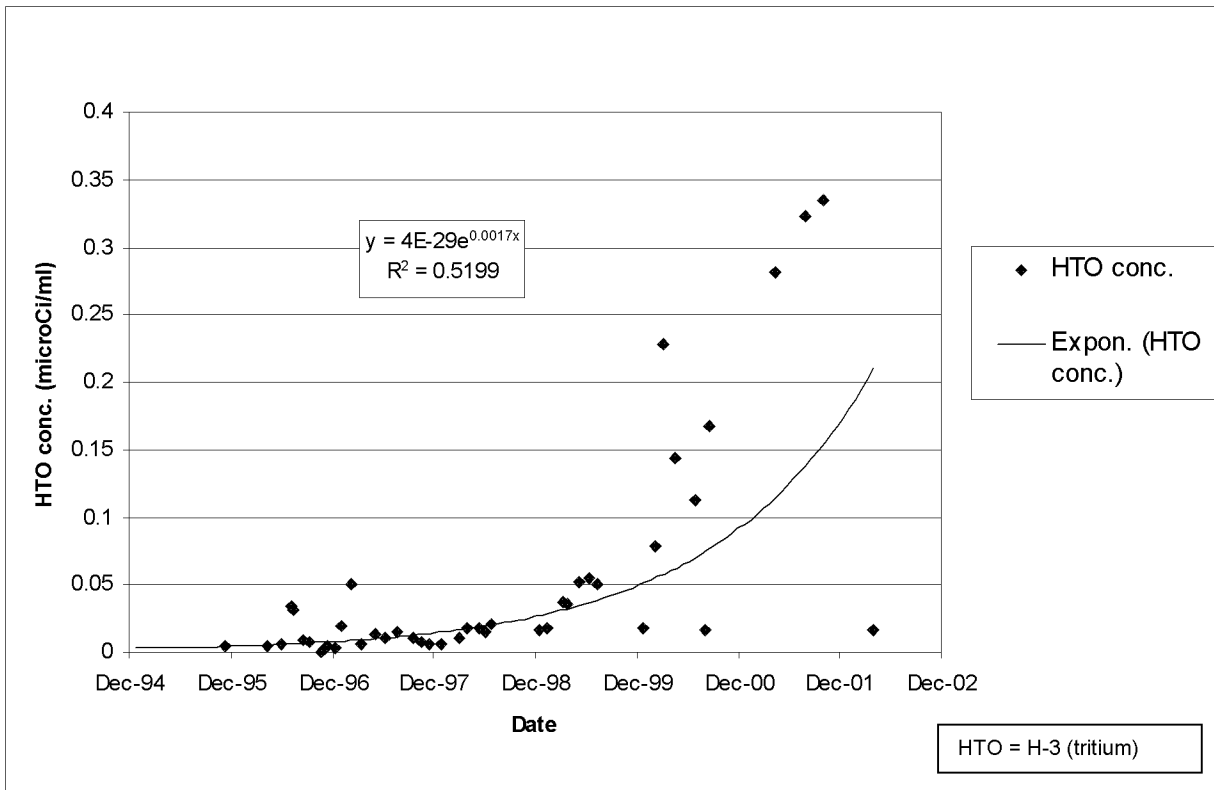


Figure 3-11. Tritium concentration in water vapor from the 15-ft deep GSP-1 soil gas sampling port.

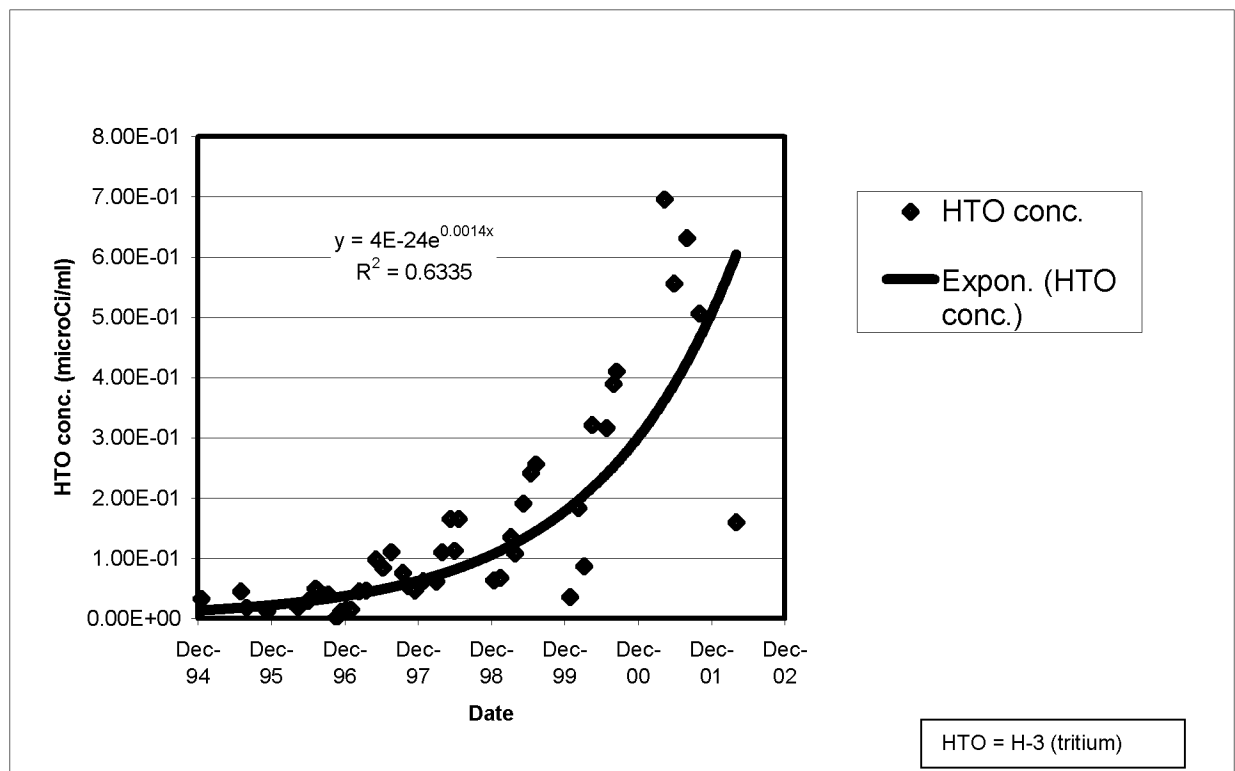


Figure 3-12. Tritium concentration in water vapor from the 20-ft deep GSP-1 soil gas sampling port.

3.4.2 Vadose Zone

Tritium has been detected in some of the routine vadose zone soil moisture and perched-water samples, with the highest concentrations found in samples from W06-L27 at about 3.7 m (12 ft) deep. Concentrations in this lysimeter had increased from FY 1997 through 1999, but no samples have been collected since then (see Table 3-9). The closest known source of H-3, relative to the location of W06-L27 is the activated beryllium at SVR 20, approximately 48 m (150 ft) to the east. Tritium was also detected in Lysimeter PA02-L16 at 2.7 m (8.7 ft) deep from 1997 through 1998. Sampling in 1999 and 2000 did not show any detections and no samples have been collected since that time.

Table 3-9. Summary of maximum concentrations of tritium in the vadose zone and aquifer at the Radioactive Waste Management Complex from FY 1997 to 2002.^a

	Fiscal Year ^b	Maximum Concentration $\pm 1\sigma$ (pCi/L) ^c	Sample Location
Lysimeters 0 to 35 ft	1997	3,270 \pm 100	W06-L27
	1998	7,290 \pm 474	W06-L27
	1999	8,650 \pm 554	W06-L27
	2000	9,100 \pm 1,180	W06-L27
	2001	NA	—
	2002	NA	—
Lysimeters 35 to 140 ft	1997	ND	D06-DL02
	1998	2,520 \pm 249	TW1-DL04
	1999	2,950 \pm 209	TW1-DL04
	2000 through 2002	NA	—
Perched water >140 ft	1997	310 \pm 35	USGS-92
	1998	1,570 \pm 188	USGS-92
	1999	ND	USGS-92
	2000	NA	—
	2001	NA	—
	2002	NA	—
Aquifer	1997	1,910 \pm 182	M3S
	1998	1,990 \pm 270	M12S
	1999	1,860 \pm 247	M14S
	2000	1,860 \pm 177	M14S
	2001	1,730 \pm 192	M14S
	2002	1,740 \pm 148	M14S

a. MCL= 20,000 pCi/L.

b. Fiscal year spans from October 1 to September 30 (e.g., October 1, 1996, to September 30, 1997, is FY 1997).

c. NA = Not analyzed. ND = **Not detected**.

FY = fiscal year

RWMC = Radioactive Waste Management Complex

Tritium also was detected in an intermediate-depth lysimeter (TW1-DL04) at about 31 m (102 ft) deep and in the perched-water well (USGS-92) at 65 m (214 ft) deep in FY 1998 and 1999. No samples have been analyzed for H-3 from Lysimeter TW1 since 1999, so it is not possible to assess trends in that well. One sample was collected from Well USGS-92 in FY 2000, but no H-3 was detected.

3.4.3 Aquifer

Detections of H-3 in aquifer samples occur regularly in Wells M3S, M7S, M12S, M14S, M16S, and M17S (see Figure 3-13), and have never occurred in Wells A11A31, M1S, M4D, M6S, M10S, M112, M13S, M15S, OW-2, or USGS-127.

FY	Qtr	A11A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	RWMC Prod	USGS-127
1997	1																	
	2																1,490	
	3											1,910			1,430		1,320	
	4																	
1998	1											1,540			1,250		1,230	
	2																1,130	
	3											1,770			1,370			
	4				1,990		1,670					1,920			1,440		1,550	
1999	1				1,610		1,860					1,410			1,260		1,600	
	2				1,360		1,870					1,710			1,400		1,500	
	3				1,570		1,710					1,600			1,400		1,600	
	4				1,390		1,740					1,700			1,420		1,500	
2000	1				1,660		1,520					1,470			1,150		1,600	
	2				1,500		1,860		1,020			1,690			1,440		1,290	
	3									836							1,140	
	4				1,370		1,640		1,480	1,010		1,760			1,250		1,500	
2001	1						1,730		1,040	613		1,360			1,150		1,040	
	2				776		889					915			802			
	3				1,480		1,470		809	533		1,270			1,110			
	4				1,640		1,520		1,170	837		1,680			1,240			
2002	1				1,120		1,240		847	507		1,260			951			
	2				1,190		1,740		1,210	678		1,600			1,450			
	3				1,620		1,790		1,250	1,110		1,320			1,120			
	4				1,380		1,600		946	608		1,090			1,020			
		Analysis performed but H-3 not detected.																
		H-3 detected (pCi/L).																
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.																
		Note: MCL=20,000 pCi/L.																
		MCL = maximum contaminant level																

Figure 3-13. Occurrences of tritium detections in the aquifer since FY 1997.

3.4.4 Summary of Tritium

There is an obvious trend of increasing tritium concentrations over time in soil vapor samples collected near the buried beryllium blocks near SVRs 12 and 20. Elevated H-3 concentrations were detected in the air samples collected above the beryllium block disposals; however, trends are not evident.

In the aquifer beneath the RWMC, H-3 is consistently measured in some of the wells, and is consistently absent in other wells. None of the wells exhibit increasing concentration trends. The consistent appearance of H-3 in some wells, and the clear pattern of detections and nondetections in the aquifer wells, suggest that H-3 may be a useful calibration target; however, many of the detections may originate upgradient from the SDA and may be caused by contributions from other facilities such as INTEC or the Test Reactor Area (TRA). Tritium data may be useful for evaluating the flow patterns around the SDA and assessing whether upgradient contaminants are impacting the quality of the aquifer beneath the SDA. Additional work needs to be performed to characterize the source of H-3 in the aquifer and to assess the potential ramifications of such a finding.

3.5 Iodine-129

Iodine-129 is produced from nuclear reactor operations and weapons testing, and occurs naturally in the environment through interactions of cosmic rays with atmospheric gases and from the spontaneous fission of U-238. Approximately 0.15 Ci of I-129 were disposed of in the SDA, primarily from INEEL reactor operations waste.

3.5.1 Waste Zone

No waste zone soil moisture samples were collected and analyzed for I-129 in FY 2002 because of arid conditions, limited sample volumes, and analytical priorities.

3.5.2 Vadose Zone

3.5.2.1 Lysimeter Samples at Depths from 0 to 35 ft. Two soil moisture samples were obtained from a depth range of 0 to 35 ft and analyzed for I-129 in FY 2002, with no positive detections. The samples were collected in July 2002. Occurrences of I-129 in shallow lysimeters since FY 1997 are shown in Figure 3-14.

3.5.2.2 Lysimeter Samples from 35 to 140 ft Deep. No soil moisture samples from the 35 to 140-ft depth interval were analyzed for I-129 in FY 2002.

3.5.2.3 Lysimeter and Perched-water Samples at Depths Greater than 140 ft. One perched water sample and no soil moisture samples were obtained at a range deeper than 140 ft and analyzed for I-129 in FY 2002, resulting in no positive detections. The perched water sample was collected from USGS-92 in January 2002. No I-129 has been detected in any wells or lysimeters from this depth range since sample collection began in 1997.

FY	Qtr	98-1L35	98-4L38	98-5L39	D15-DL07	PA01-L15	PA02-L16	PA03-L33	W05-L25	W06-L27	W08-L13	W08-L14	W09-L23	W23-L07	W23-L08	W23-L09	W25-L28
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1	53		29													
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
Key		Analysis was performed, but I-129 was not detected.															
		I-129 detected (pCi/L.)															
If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.																	
Note: RBC=3.22 pCi/L																	
RBC = 1E-05 risk-based concentration																	

Figure 3-14: Occurrences of iodine-129 detections in shallow lysimeter wells.

3.5.3 Aquifer

Sixty-three aquifer samples were collected from 15 RWMC monitoring wells in FY 2002 and analyzed for I-129, resulting in no positive detections. Samples were collected in November 2001, December 2001, February 2002, May 2002, and September 2002, from monitoring Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127.

A special sampling and analysis event, outside the scope of routine WAG 7 aquifer monitoring, was conducted in May 2002 to determine whether I-129 might be present in the aquifer beneath the RWMC at concentrations below standard method detection limits (i.e., 1 pCi/L). Fifteen, 6-L samples were collected from 14 RWMC aquifer monitoring wells and analyzed for low-levels of I-129 with an analysis technique developed by the Analytical Laboratories Department at TRA. The analytical technique is capable of achieving detection limits more than 10 times lower than routine I-129 methods. The samples were collected from Wells AllA31, M1S, M3S, M4D, M6S, M7S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127. The analytical method attained minimum detectable activities (MDAs) between 0.05 and 0.07 pCi/L, and no aquifer samples tested positive for I-129 at these low concentrations.

3.5.4 Summary of Iodine-129

No I-129 was detected in soil moisture samples collected in FY 2002 from the SDA vadose zone, or from water samples collected from RWMC aquifer monitoring wells. Historical detections in the vadose zone and perched water are sporadic and not indicative of trends. Figure 3-15 depicts the I-129 detections with the known I-129 disposal locations. The detection of I-129 in soil moisture from Lysimeter 98-1L35, at a depth of 5 m (16.5 ft), is the only detection that occurred near a mapped disposal location. The three lone detections depicted in Figure 3-14 were not substantiated in later sampling events. Tables 3-10 and 3-11 summarize the maximum I-129 concentrations detected in vadose zone and aquifer samples since FY 1997, respectively. Detections are sporadic and not indicative of trends or widespread contamination. The absence of I-129 in the aquifer around the RWMC, as determined by the special study conducted in May 2002, provides evidence that I-129 is not present in the SRPA in or around the RWMC.

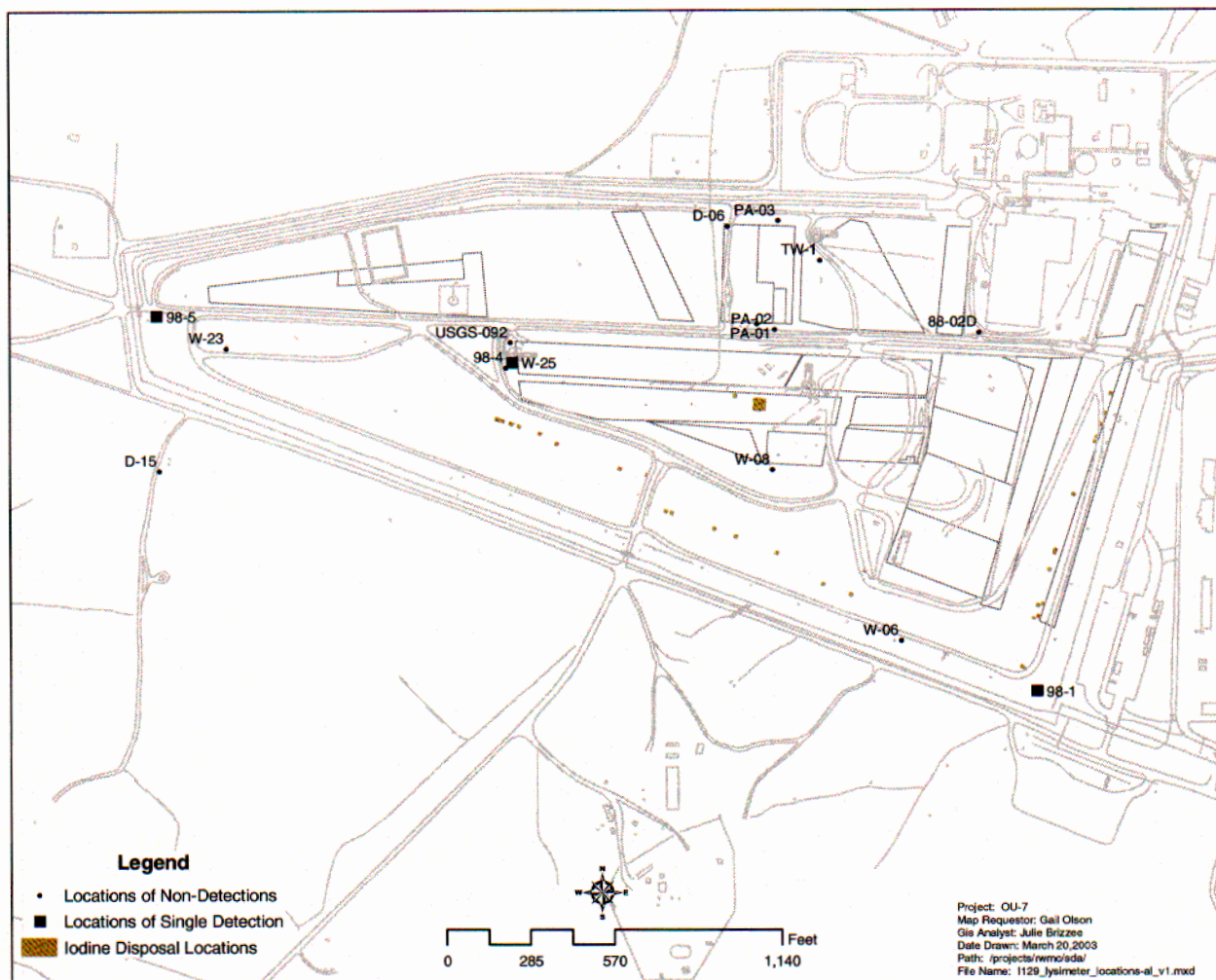


Figure 3-15. Iodine-129 disposal locations and vadose zone detection locations at the Subsurface Disposal Area.

Table 3-10. Summary of maximum iodine-129 concentrations in vadose zone soil moisture and perched-water samples at the Radioactive Waste Management Complex from FY 1997 through 2002.^a

Sampling Range (feet below land surface)	Fiscal Year ^b	Maximum Concentration $\pm 1\sigma$ (pCi/L) ^c	Sample Location
Lysimeters 0 to 35 ft	1997	ND	Various ^d
	1998	ND	Various ^d
	1999	53 \pm 18	98-1L35
	2000	22 \pm 7	W25-L28
	2001	NA	—
	2002	NA	—
Lysimeters 35 to 140 ft	1997	ND	D06-DL02
	1998	ND	Various ^d
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
Perched-water wells >140 ft	1997	ND	USGS-92
	1998	ND	8802D
	1999	ND	USGS-92
	2000	NA	—
	2001	NA	—
	2002	ND	USGS-92

a. MCL = 1 pCi/L.

b. Fiscal year spans from October 1 to September 30 (e.g., October 1, 1996, to September 30, 1997, is FY 1997)

c. NA = Not analyzed. ND = Not detected.

d. Various locations were sampled.

FY = fiscal year

MCL = maximum contaminant level

Table 3-11. Summary of maximum aquifer detections of I-129 in the aquifer around the Radioactive Waste Management Complex from FY 1997 to 2002.^a

Fiscal Year ^b	Maximum Concentration $\pm 1\sigma$ (pCi/L) ^c	Well Location ^d
1997	1.7 \pm 0.4	M10S
1998	1.0 \pm 0.2	M1S
1999	1.5 \pm 0.4	M7S
2000	ND	Various
2001	ND	Various
2002	ND	Various

a. MCL = 1 pCi/L.

b. Fiscal year spans from October 1 to September 30 (e.g., October 1, 1996, to September 30, 1997, is FY 1997).

c. ND = Not detected.

d. Various locations were sampled.

FY = fiscal year

MCL = maximum contaminant level

3.6 Neptunium-237

Neptunium-237 is a transuranic (TRU) isotope that is a product of nuclear reactor operations and is a decay product of Am-241. Approximately 2.6 Ci of Np-237 was disposed of in the SDA, and approximately 37 Ci of Np-237 are expected to be produced over time from Pu-241 and Am-241 ingrowth.

3.6.1 Waste Zone

Two waste zone soil moisture samples were collected in FY 2002 and analyzed for Np-237, with two positive detections (see Table 3-12). Both samples were collected from Lysimeter 741-08-L1, which is located in the Americium/Neptunium Focus Area in Pit 10.

Table 3-12. Neptunium-237 detections in Subsurface Disposal Area waste zone soil moisture (lysimeter) samples.

Lysimeter	Depth (ft)	Sample Date	Sample Volume (mL)	Sample Concentration $\pm 1\sigma$ (pCi/L)	Minimum Detectable Activity ^a (pCi/L)	Samp Identifier	Limitations and Validation Report Identifier
741-08-L1	15.2	11/7/01	~15	22 \pm 6 _p ^b	11	IPL006013A	DNT-060-02
741-08-L1	15.2	4/29/02	~20	6.1 \pm 1.7	3.1	IPL057013A	SOS-019-02

a. The MDA is commonly referred to as the detection limit and is an analysis result unique to each individual sample.

b. Red bold font indicates a sample concentration exceeding the RBC of 7.1 pCi/L. The RBC does not apply to soil moisture samples and is provided only as a basis for comparison. The subscript "p" denotes a positive and validated detection that the project technical team deems questionable. The result is questionable because Np-237 was not detected in the laboratory-generated duplicate, and the laboratory control sample result had a low bias. Therefore, the result can be used only as an estimated quantity.

RBC = 1E-05 risk-based concentration

3.6.2 Vadose Zone

3.6.2.1 Lysimeter Samples from 0 to 35 ft Deep. Nine soil moisture samples were obtained in FY 2002 from the depth range of 0 to 35 ft and analyzed for Np-237, resulting in no positive detections. Five samples were collected in April 2002 from Lysimeters PA01-L15, W06-L27, W09-L23, W25-L28, and 98-4L38. Four samples were collected in July 2002 from Lysimeters PA01-L15, W23-L07, W23-L09, and W25-L28. No Np-237 has been detected in shallow lysimeter samples since monitoring began in FY 2000.

3.6.2.2 Lysimeter Samples from 35 to 140 ft Deep. Eleven soil moisture samples were obtained in FY 2002 from a depth range of 35 to 140 ft and analyzed for Np-237, resulting in no positive detections. Three samples were collected in April 2002 from Lysimeters I1S-DL09, I2S-DL11, and I4S-DL15. Eight samples were collected in July 2002 from Lysimeters D15-DL06, I1S-DL09, I2S-DL11, I3S-DL13, I4S-DL15, O3S-DL22, O4S-DL24, and O5S-DL25. No Np-237 has been detected in intermediate-depth lysimeter samples since monitoring began in FY 2000.

3.6.2.3 Lysimeter and Perched-water Samples Deeper than 140 ft. One perched water sample and seven soil moisture samples were obtained in FY 2002 from the range deeper than 140 ft and analyzed for Np-237, resulting in no positive detections. The perched water sample was collected from USGS-92 in January 2002. Four samples were collected in April 2002 from Lysimeters I2D-DL10, I3D-DL12, I4D-DL14, and O8D-DL29. Three samples were collected in July 2002 from Lysimeters I3D-DL12, O6D-DL26, and O7D-DL27. No Np-237 has been detected in any samples collected at this depth since monitoring began.

3.6.3 Aquifer

Sixty-three aquifer samples were collected in FY 2002 from 15 RWMC monitoring wells and analyzed for Np-237, resulting in three unconfirmed detections (Table 3-13). The three samples with positive detections were reanalyzed and showed no positive detections. Samples were collected in November and December 2001, and February, May, and September 2002, from monitoring Wells A11A31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127. These are the first detections of Np-237 in RWMC monitoring wells since monitoring for Np-237 began in FY 1999.

3.6.4 Summary of Neptunium-237

Neptunium-237 was detected in two waste zone lysimeter samples collected in FY 2002 from the Americium/Neptunium Focus Area. The location of this lysimeter is shown in Figure 3-15 along with the known disposal locations of Np-237. Not depicted are the Am-241 disposals, which contribute to Np-237 accumulation through ingrowth. The Am-241 disposal locations are depicted in Figure 3-4.

Detections of Np-237 have been found in the vadose zone or perched water since monitoring began. Three unconfirmed Np-237 detections were made in the aquifer in FY 2002, the first detections since monitoring began in FY 1999. One of the three detections (Well USGS-127) is about 5 mi upgradient, another (Lysimeter A11A31) is about 1.5 mi downgradient, and Well M16S is relatively close to the SDA, but represents the lowest concentration of all three detections. The maximum detected concentrations in the vadose zone and perched water are provided in Table 3-14, and the maximum concentrations in the aquifer are presented in Table 3-15.

Neptunium-237 has been only recently detected in samples collected around the RWMC. The detections have occurred in the waste zone and aquifer, but not in vadose zone or perched-water samples. It is not possible to detect any discernable patterns from the detections, and not yet possible to use Np-237 as a modeling target.

Table 3-13. Neptunium-237 detections in Radioactive Waste Management Complex aquifer monitoring wells.

Well	Sample Date	Radionuclide	Detected Concentration $\pm 1\sigma$ (pCi/L)	Reanalysis Result ^a $\pm 1\sigma$ (pCi/L)	Minimum Detectable Activity (pCi/L)	Maximum Contaminant Level (pCi/L)	Sample Identifier ^b
AllA31	5/21/02	Np-237	0.38 \pm 0.04	Not detected (0.003 \pm 0.010)	0.05	15 ^c	RISM7301RH
M16S	5/15/02	Np-237	0.08 \pm 0.02	Not detected (0.007 \pm 0.008)	0.06	15	RISM7001RH
USGS 127	5/21/02	Np-237	0.26 \pm 0.04	Not detected (-0.02 \pm 0.04)	0.05	15	RISM7201RH

a. A sample is reanalyzed if the analytical result for Am-241, Np-237, Pu-238, or Pu-239/240 is greater than its sample-specific MDA and greater than two times its reported 1 σ standard deviation. The reanalysis provides information necessary to help evaluate and confirm detections.

b. The limitations and validation report identifier associated with each sample identifier is DNT-190-02.

c. The primary drinking water MCL of 15 pCi/L is established for and applicable to total alpha, not to each individual alpha-emitting radionuclide.

MDA = minimum detectable activity

MCL = maximum contaminant level

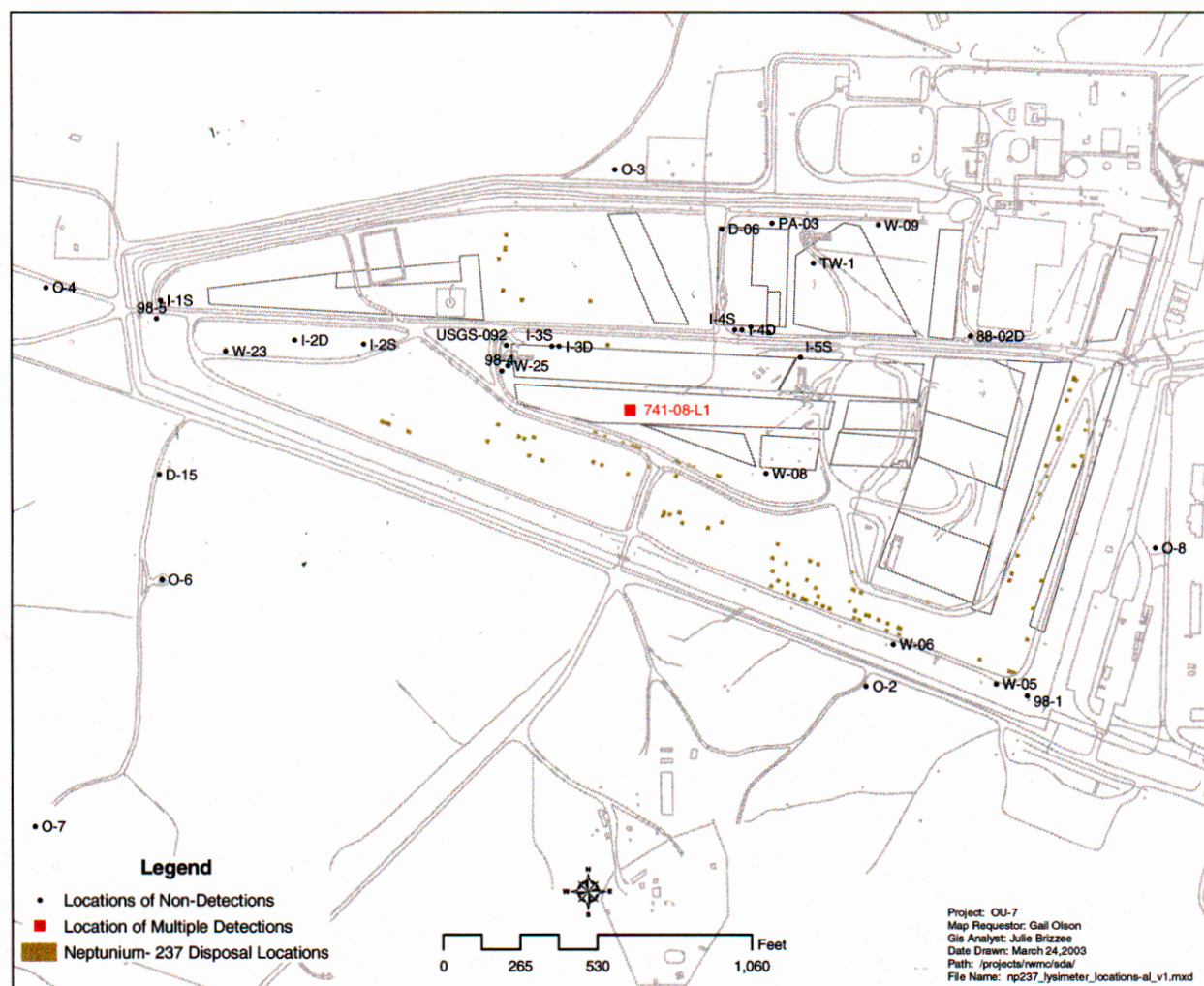


Figure 3-16. Disposals and detections of neptunium-237 in the vadose zone soil moisture samples.